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Pink Salmon Disparity: Toward Definition

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PINK SALMON DISPARITY; TOWARD DEFINITION

by

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Frontispiece - Sunshine and flat boom in Chatham Sound in 1938 (M.V. *F.H. Phippen*, J.M. Morrison, Master).

ABSTRACT

Barber, F. G. 1980. Pink salmon disparity; toward definition. Can. MS Rep. Fish. Aquat. Sci. 1594: 20 p.

Dominance in pink salmon populations as characterized by extreme disparity and barren streams is investigated through consideration of field experiment.

Key words: pink salmon, extreme disparity, barren streams, predation, field experiment, sea-going pens.

RÉSUMÉ

Barber, F. G. 1980. Pink salmon disparity; toward definition. Can. MS Rep. Fish. Aquat. Sci. 1594: 20 p.

L'auteur étudie, suite à des expériences sur le terrain, la dominance dans les populations de saumon rose, qui se caractérise par une extrême disparité et des cours d'eau sans poisson.

Mots clés: saumon rose, extrême disparité, cours d'eau sans poisson, prédation, expérience sur le terrain, parcs d'élevage en mer.

> We should develop models of particular biological processes like predation which can be used as building blocks in future, larger systems (Anon. 1980a, p. 11).

The predation model I am concerned with here could, if pursued, extend understanding of the consequences of interaction within and between stocks of Pacific salmon, and between salmon and the fishery. Although I provide little new data, I believe I achieve additional insight through reconsideration of present knowledge and through development of experiment. A referee recommended against publication and commented that rather than a report on research results, the work constitutes a research proposal. Hopefully this is in part true; however, the same referee indicated little understanding of extreme disparity in pink salmon and wondered why I did not provide data on even-year fish of the Fraser River. I admit to some preoccupation with extreme disparity, but to be unaware of the distribution of extreme disparity is to be unaware of a major and intriguing problem in fishery science (Neave 1952).

Peterman (1978) examined types of interaction that may occur between some salmonids, but neglected size-selective predation by adult on young. Following from the likelihood that adult pink cannibalize fry (Ricker 1962a; 1973, p. 1283; see Note 1 here) and that extreme disparity in the distribution of pink salmon results from cannibalism (Barber 1979), I presented the regression of size of even-year adult pink salmon on the abundance of pink and sockeye returning the previous year to the Fraser River (Barber 1980 and Fig. 1 here).

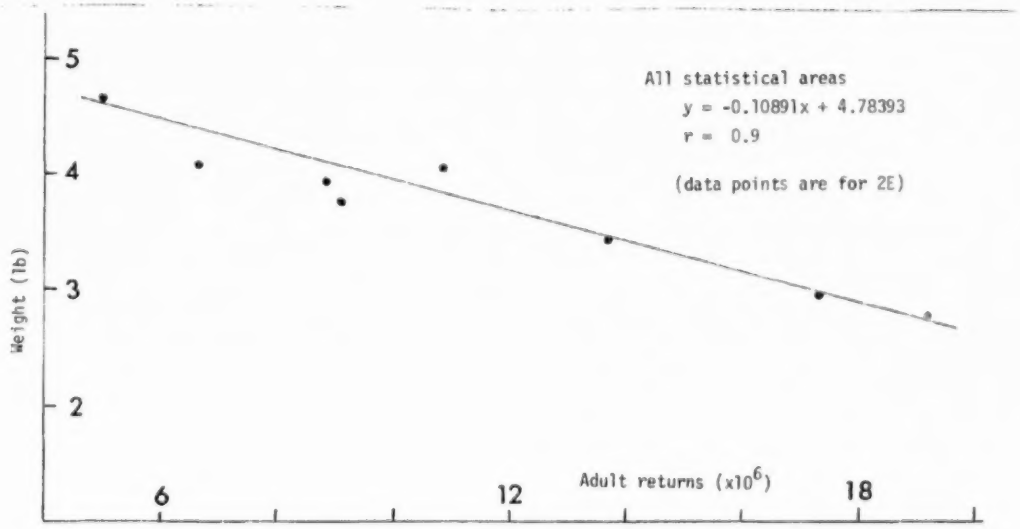

Fig. 1. Relation between the sum of the number of adult pink and sockeye estimated to have been returning to the Fraser River in each of the eight odd years 1959 to 1973 and the mean whole weight of pink salmon caught by seine each following year 1960 to 1974 in ten statistical areas of British Columbia. The eight points shown are for statistical area 2E, i.e. the east coast of the Queen Charlotte Islands (from Barber 1980).

I concluded that the strong inverse correlation could only result from a predation selective for larger fry and suggested that the geographical cline in size of both pink and sockeye populations resulted from such predation.

I had speculated that barren streams in the distribution of pink salmon were also the result of cannibalism and that tidal motions and fry behaviour (startle response) have a role in the mechanism of predation (Barber 1979). The particular behaviour wherein larger fry in a school are further offshore (Gilhousen 1962, p. 107; LeBrasseur and Parker 1964; Kaczynski et al. 1973) could also have significance, i.e. the distribution of fry in a school may be size dependent and so couple with the distribution of adult to cause size-dependent predation. As the selection is for large size, smaller (slower-growing cohorts?) in a school are buffered against predation, so that faster growth of young need not mean improved survival (Walters et al. 1978, p.1314) as has been indicated in some, but not all, sockeye systems (Foerster 1954; Ricker 1962b, 1966, p. 65; Peterman 1978, p. 1438). Biette and Geen (1980, p. 207) remarked that data supporting the latter idea "are generally scarce", but suggested a particular behaviour of sockeye smolt - diel vertical migration in the presence of limited rations - was selected for because the resulting more rapid growth improves survival (Note 2). If it does, then predation selective for larger fry may be maladaptive (Barber 1980), but as the distribution of dominance may be variable (Neave 1952) it is not possible that a particular response or strategy at the level of the individual could become adaptive (Barber 1979), except that he maximize reproduction (Preston 1969, p. 6). So I too became persuaded that where dominance occurs in pink salmon the observed returns likely represent the maximum average possible in the natural environment (Ricker 1962a, p. 195), but without understanding the mechanism of dominance (Note 3). Field experiment to further such understanding was suggested (Barber 1979, p. 4) and here I narrow consideration to outline experiment based on a model which includes an interpretation of extreme disparity and barren streams. Speculation continues common to each interpretation for although fry-adult interaction is strongly indicated, little is known about the distribution of the interaction. For example in my scheme for barren streams the interaction is maximum in areas of the coast lying between the inshore (mainland fjords and inlets) and the offshore (seaward of the shelf), so that a gradient in the interaction, i.e. in the intensity of predation, is likely. Extreme disparity also should be associated with such a gradient. Detection of these gradients from their expression in existing pink salmon populations is proposed.

That a gradient exists in the interaction is supported by the distribution of correlation coefficient (Fig. 2) derived for each statistical area from the regression of size of even-year fish on abundance of odd-year fish returning to the Fraser (Note 4). In this the area of strongest correlation is shown as a tongue-like distribution extending from the east Queen Charlottes to the Nass River and there is a tongue of relatively high values extending from seaward into Queen Charlotte Strait, i.e. into area 12. The value for the area about the Nass, area 3, is high and cannot be said to fit my scheme of the distribution of the predation, for the low surface salinity in summer north of Chatham Sound (Fig. 3) suggests an inshore area of less interaction. As fish caught in area 3 are likely to be returning to streams there I was led to consider that size-selective predation on fry from these streams occurred further seaward.

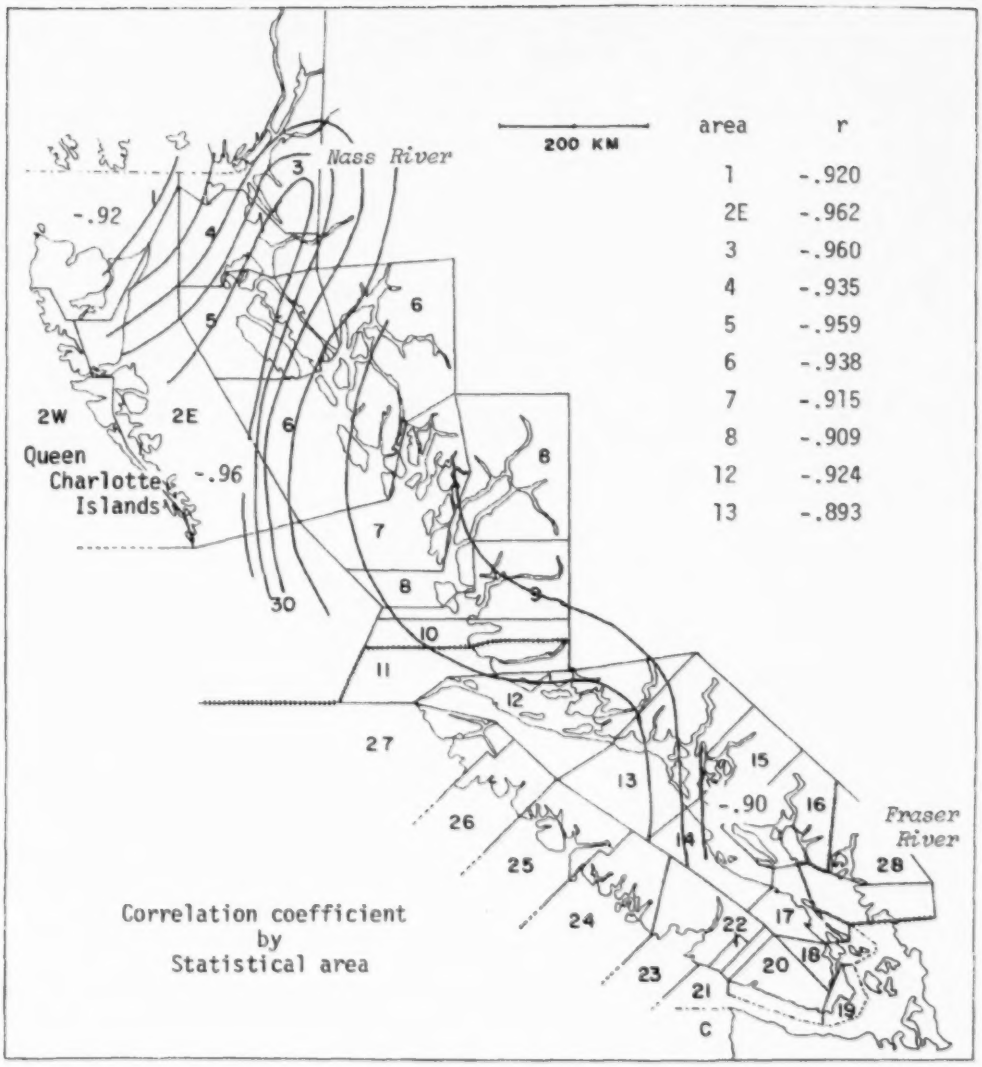

Fig. 2. An interpretation, necessarily somewhat fanciful (Note 4), of the distribution of the coefficient of correlation (r) as derived for each of the ten statistical areas (see tabulation in figure) from the eight years of data of Fig. 1. (Base map from Ricker et al. 1978).

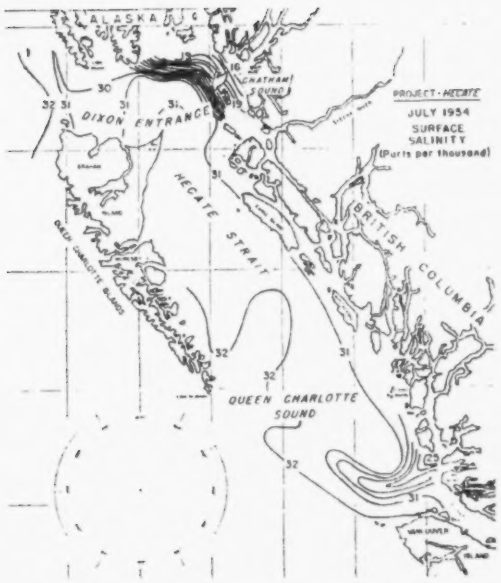

Fig. 3. The distribution of surface salinity in summer from Queen Charlotte Sound to Dixon Entrance (from Barber and Tabata 1954; see also Dodimead 1980).

This does not presuppose understanding of the distribution, for it is a character of homing that the closer the statistical area be associated with a specific spawning area the more likely salmon caught in the statistical area are returning to streams there (e.g. Ricker 1972, p. 29). But as suggested by the relatively high surface salinity, close to 32 $^{o}/_{oo}$, area 2E is more representative of a coastal region and here the strongest correlation occurred (see tabulation in Fig. 2). I speculate that this correlation is the consequence of a size-selective predation on fry from that area, i.e. area 2E, by adults intending to return that odd year to the Fraser. These adults comprise both homesteaders, i.e. fish that do not move into the ocean further from the Fraser than Hecate Strait (Barber 1979), and true ocean migrants. Homesteaders were believed responsible for the distribution of barren streams, which in turn suggests a distribution of homesteaders (from all streams) throughout the open coast of British Columbia including Queen Charlotte Sound, Hecate Strait and Dixon Entrance. On the other hand, areas of extreme disparity (for which data cannot be contrived for the off year except the population is zero) is believed the consequence of interaction between fish (adult and fry) from the same local area in a response to tidal motions (Barber 1979).

Extreme disparity then in pink salmon is a form of dominance in which the adult to a particular stream would impact through cannibalism (Note 5) the other year class to the same stream, were the other year class to exist,

whereas a barren stream is the result of the impact of the adult from a distant stream. Each stream lies within a zone from which off-year young from the stream would not emerge if released there, i.e. the probability of survival of the young is zero. Beyond is a transition region in which the probability of survival (for those fry from the stream that are released there) increases toward an area where the survival probability of fry is relatively high and constant, i.e. toward an on-year area for the year class.

The concept of a gradient in the intensity of predation may have resulted through reading Vermeij (1978); however, I present the concept as a probability of survival rather than his "pressure of predation" because barren streams and extreme disparity appear characterized by areas of zero survival in which the actual, or potential, predation pressure is not known. Some modification to the scheme occurred after the dependence was seen in size of pink on the abundance of pink and sockeye adult returning to the Fraser River and the implication therein that salmon adults prey on young generally (Barber 1980). The complement of maturing fish in coastal water would comprise adults returning to natal streams as well as others, immatures (LeBrasseur 1966, p. 86), with a year or more to spawning, but little is known about distributions except during movement into freshwater as spawning adult. The impact of adult on fry would also reflect seasonal changes in feeding (LeBrasseur 1972) and on the time and location mature fish cease feeding. "Actively feeding pink salmon" are caught in "inside waters" like Johnstone Strait, Strait of Georgia and the Strait of Juan de Fuca (LeBrasseur and Parker 1964, p. 1125), but not in the mainland fiords and inlets.

EXPERIMENT AT OTARD CREEK AND MASSET INLET

I remarked that extreme disparity provides unique opportunity through experiment to improve understanding of pink salmon distributions (Barber 1979); unique because experiment:

1) could provide unequivocal data over the life span of but a single year class,
2) could be repeated and
3) could avoid long-term adverse effects.

Consider a stream which now exhibits extreme disparity: should a significant number of adults return in an off-year subsequent to an experiment there with just such an objective, it could fairly be assumed that the experiment was successful. As the progeny of these adults would not survive (the process of extreme disparity), the creek remains barren in the off-year and the experiment concluded without adverse interaction with other stocks (McDonald and Bams 1974). Several such experiments to illuminate the mechanics of disparity in pink salmon appear possible; they would depend in part on growing experience in aquaculture (e.g. Ayles and Brett 1978) and on limited understanding of the geographical distribution of disparity (Neave 1952) in relation to the migration routes of sea-going young and stream-bound adult (Royce et al. 1968). To avoid interaction of adult and fry, the adult may be harvested early or the fry contained for later release or for transport to a release point beyond the returning adult. In the two experiments below only the

young are manipulated, containment and transport being achieved with sea-going pens (Note 6).

Would the return of even-year pink to Otard Creek (Note 7) increase were fry from the creek in an odd-year transported to a release point in an area where even-year runs occur? A positive result would support the consideration that some adult salmon of the odd-year class to other streams exist in the ocean nearby the creek and interact there with sea-going fry. Otard Creek is close to the ocean and appears to have potential for experiment, being barren in the odd-year and nearly so in the even-year (Marshall et al. 1978a, p. 170). Surface salinity in Otard Bay in summer can be relatively high (32 $^{o}/_{oo}$), reflecting the near-ocean location, with summer surface temperature likely less than 15°C (Fig. 4).

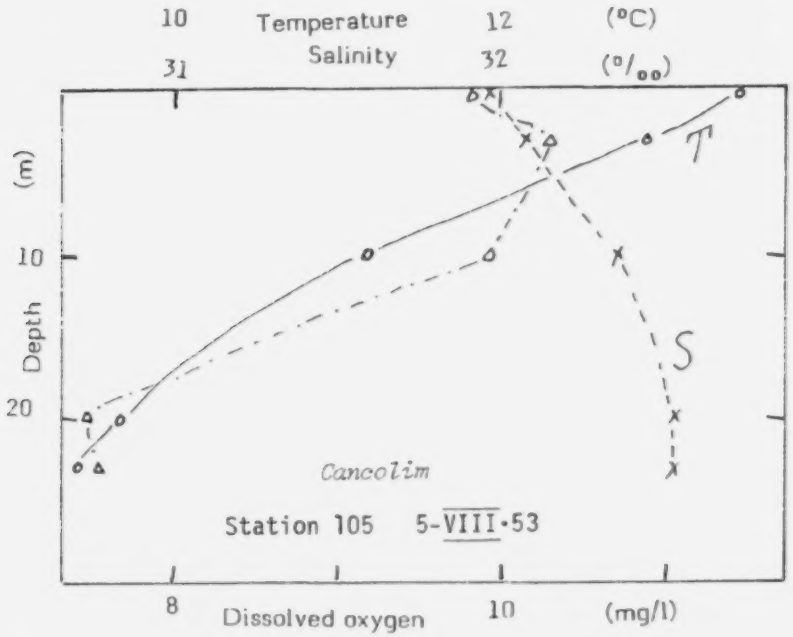

Fig. 4. Distributions with depth of salinity, temperature and dissolved oxygen in Otard Bay in August 1953 (from Anon. 1955, p. 43). The bay is a relatively small indentation in the ocean coastline of Graham Island and, as suggested by the distributions, is freely connected to the ocean.

The local area is also barren (Note 8) in odd years and northern Graham Island has large runs in even years only, so the adult returning to the creek in an even-year could not interact with the young from local streams (as the young do not exist); I believe there is a sufficient even-year escapement to Otard Creek (Marshall et al. 1978a, p. 172) to permit the experiment. In order to

further outline the scenario I conjecture that some fry survive to return as adult and that the distribution of the number of returns relative to the site of release fits the scheme described, i.e. a zone from which there was minimum or no return would be defined with a transition region of increasing survival to an area of relatively high adult survival.

The Masset system and the many small streams into it have been suggested suitable for a variety of experiment, including enrichment (Anon. 1980b, p. 17) and transport of fry to a release point outside the system (Barber et al. 1975; Barber 1979). The latter suggestion was based on the considerations that pink fry "readily tolerate full-strength sea water" (Brett 1974a; see also Weisbart 1968 and Note 9) and that the cannibalism causing extreme disparity occurs within or close to the system. Consider the result were fry of the off-year planted in one of the small streams there subsequently released in equal numbers at each of several points between Masset Inlet and the ocean: I visualize the transplant of eggs from Tlell River to McClinton Creek as in earlier trials there (Pritchard 1938), then transport of fry from the stream in the sea-going pens and eventually the definition of a gradient of survival from return of adult as in the experiment at Otard Creek.

The two experiments could give insight to the general problem of disparity, but cannot be said to be well-defined in consideration of the host of variables which in the absence of understanding seem likely to complicate them, in particular to complicate the Masset experiment as it requires transplant of young in some form (Ricker 1972, p. 101-2; McNeil et al. 1969). Both experiments would benefit from the earlier work at Masset, e.g. Pritchard (1938) and Cameron (1958), and from recent and similar experiments, e.g. Bilton (1978). Following Bilton the object of the Otard experiment is to rear, and imprint a population of pink fry for release at a number of locations between the creek and an on-year area and to provide a means by which the returns from each release might be compared (Note 10). Fry of the even-year class are captured as they enter the estuary from the creek and contained in one of the sea pens. When it is judged that all, or most, fry are out of the creek the pens are slowly moved close along the coast to the vicinity of Cape Knox and then eastward into Dixon Entrance. During the move (which needs to take about two weeks for adequate imprinting) the fry are separated into nine populations, marked and tagged. The first release of a population is made close-in to Cape Knox and the subsequent 8 releases are made at equal separation along a line ending close inshore off Wiah Point. At Masset the object is to rear and imprint a population of pink fry of the off-year class for release at a number of locations seaward of the home creek and to provide means by which the returns might be compared. By transplant of young, nine populations would again be achieved, then tagged and released at nine positions beginning at McClinton Creek and again ending close inshore off Wiah Point.

DISCUSSION

Pink salmon "offer the hope of initiating a valuable new fishery while avoiding competition with native fishes for the food supplies of the freshwater habitat" (Neave 1965, p. 1); the opportunity exists because some rivers and streams characteristically have "off" years (Neave 1952; Ellis and Noble

1959). There have been numerous attempts to exploit this peculiarity in the distribution of pink salmon and while not successful they provided considerable information (Neave 1965). In addition pink salmon appear relatively efficient in their utilization of the ocean food resource in terms of net growth (Brett 1974b; p. 81); however, interest here is to the possibility that the cause of extreme disparity is unique (cannibalism). I restrict consideration to barren areas and areas of extreme disparity as size selection of young by adult does not appear to be a factor in the existence of the areas and as the interactions there may be better defined than elsewhere. My purpose then is to attempt some definition, through consideration of experiment, of the interaction underlying the existence of extreme disparity and barren streams in pink salmon, but without consideration of the potential consequences of such experiments in the context of enhancement (e.g. Peterman 1978, p. 1448) or of harvesting strategies (e.g. Walters 1975). I was taken with Larkin's (1979a, p. 105) complaint that the fishery is not "productive of new knowledge" in that it is not recognised as "a potential variable to be manipulated" (see also Larkin 1978, p. 65; 1979b, p. 27). I had supposed that regulation of the troll fishery to effect shutdowns would ensure larger fish in the escapement, and so arrest the decline in size (Ricker et al. 1978; Barber 1980; see also Ricker 1980, p. 14), and I now suppose that the recent decline in abundance of pinks to the northern Queen Charlotte Islands (Wood 1977) reflects a change in the character of the streams there from extreme disparity toward barren in both years. The trend could develop if seagoing young of the even-year class were being increasingly preyed on by adults from, and returning to, streams elsewhere along the coast. Suppose too that during one odd-year the intensity of fishing was increased in Dixon Entrance and the adjacent ocean (beyond the surf line) so that the number of these adults were much reduced. Would a result be an increased return to Masset the following year? I believe it would, but whether it would be discernable as an increase in abundance directly related to the change in location of fishing effort is not certain. However, it should be discernable as an increase in mean whole weight the following even year, i.e. given an estimate of the fish returning to the Fraser in the odd-year (Note 11) then the mean whole weight of seine-caught fish in all statistical areas the following year should lie significantly above the regression line derived from statistics on the normal fishery (Fig. 1).

Whether such an increase in fishing effort in one particular season could be arranged is not important here beyond the extent the idea further illustrates the model; however, the possibility the northern Queen Charlotte Islands (statistical area 1) is becoming barren in both years needs elaboration. According to the model this would require a change from cycle, or line, dominance, i.e. of on-year fish over off-year fish, to one of dominance in both years of fish from other areas. Ricker (1962a) reviewed experience around the North Pacific relative to line dominance and reversals of dominance in pink salmon; he noted (p. 169) that "there is no known example of a weak line increasing to a condition of equality with the dominant line while the latter remains abundant." Such circumstance would not fit the model so is not anticipated, but equally there is no evidence of a strong line decreasing to a condition of equality with a non-dominant line while the latter remains sparse. This of course does fit the model, so I anticipate it could be occurring in statistical area 1, i.e. the area is becoming barren in both years. In order to depress the on-year and to maintain the off-year in the absence of dominance of on-year fish, the intensity of the interaction by

adult from other areas must be increasing each year.

The concern expressed about the apparent decline of the on-year run to area 1 (Wood 1977) is supported by recent escapement data (Brown and Musgrave 1979); however, I have not found specific comment earlier than that of Howe (1933, p. E6; Note 12) about the character of the populations there. I note the remarks of Ricker (1962a, p. 184) that extreme dominance in the Masset system "apparently existed from the earliest times" and of Cobb (1914, p. 32) that the Puget Sound area was "the only place on the coast" where "a large run appears every other year." As cannery operations did not begin at Masset until 1910 (Dalzell 1968, p. 298) and as pink salmon had only become of interest to the fishery, even in the Fraser area, by about the same time (Lyons 1969, p. 282), Cobb may not then have been aware that to statistical area 1 a large run appeared every other year.

There is then no reason to believe that the distribution of extreme disparity just prior to the establishment of the fishery was different than at present, i.e. the fishery does not appear to have had an influence on the distribution of extreme disparity. On the other hand, some changes in dominance less marked than as in extreme disparity may have been due to a reduction in adult escapement by the fishery, e.g. the Skeena in 1932 (Neave 1966). But removal of adults may reduce adult-young interaction, at least this is what I suggest, with which would be associated an increase in marine survival of young. Consider the evidence of the characteristic "fishing-up period" associated with a fishery on adults of a species with a number of age groups in that the "sustainable yield is likely to be half or less than half of the early maximum" (Ricker 1973, p. 1276). This fishing-up period has been attributed to "the removal of accumulated stocks" (F.I. Baranov according to Ricker 1973; Note 13), but could equally be due to a decrease in competition between adult and young, in particular a decrease in cannibalism by adult on young. For the same reason a fishing-up period could be anticipated of runs of Pacific salmon; Ricker's (1973, p. 1276) comment that runs of Pacific salmon "fail to produce at levels close to what has generally been expected of them on the basis of their past history" suggests this is so.

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NOTES

1) C. E. Walker, British Columbia Hydro and Power Authority, in a personal communication noted that at Uyak Bay, Kodiak Island "on one occasion an adult pink salmon caught on trolling gear had a pink in its stomach"; this is the only record of cannibalism in pink salmon.

> ...if it were to be found that there is any appreciable consumption at all of small pinks by large pinks, cannibalism would automatically become a prime suspect as a factor which perpetuates *and intensifies* inequality between the lines. Experimental observation is seriously handicapped, of course, by the fact that areas where the effect of cannibalism is most important would be those where extreme dominance prevails naturally, so that the scarcity of the off-year fish makes it difficult to find them in the stomachs of the dominant line. (Ricker 1962a, p. 185).

The relation of Figure 1 indicates "appreciable consumption" of fry by adult so that fry should be looked for in the stomach of adults. But why have not pink fry been observed as food items of the adult? An important consideration is that pink fry were not anticipated in the stomach of the adult; certainly I was not able to find comment by an investigator that he searched specifically for pink fry, despite Neave's (1965, p. 15) comment "Pink salmon fingerlings have not yet been found in stomachs of adults of the species." Another is that some samplings of the pink adult have occurred at times and places (LeBrasseur and Barner 1964; LeBrasseur 1966, p. 86) fry do not occur (Manzer 1956; Fukataki 1967; Barraclough and Phillips 1978). This seems now not applicable to the work of either Allen and Aron (1958) or Andrievskaya (1958), although Allen and Aron (p. 3) indicated that identification of stomach contents further than "fish" was not possible and the observation of greenling by Andrievskaya suggests the possibility that identification can be a problem (Phillips 1977). Curiously, pink fry have been seen to be eaten by coho parr and smolt (e.g. Parker 1971, p. 1510) but not by the coho adult, e.g. Prakash (1962) and others. Do coho stop preying on pink fry after smolting? Not likely. And if not likely, why are not pink fry found in adult coho stomachs? Only recently have fingerling chinook been found in yellow perch (Dahle 1979) and only recently some believed Pacific salmon to be mainly plankton eaters, i.e. "strictly planktivorous" (Sibert et al. 1977, p. 650). The general result is that a program of stomach sampling (Windell and Bowen 1978) based narrowly on present evidence might be pursued, and as the relation of Figure 1 includes pink adults returning to the Fraser, only Fraser adults should be sampled; mean whole weight would likely be an appropriate method of identification (Ricker et al. 1978).

2) Miller (1979, p. 787) cautioned against new studies of the "adaptive advantage of vertical migration" and suggested that the definitive experiment to determine the selective advantage of behaviour is usually not possible.

3) I foresee that the interaction of adult and fry in salmon areas around the North Pacific Ocean could be assessed through fishery statistics, as in Figure 1, and by experiment. I believe that degrees of dominance are characteristic of Pacific salmon and as dominance is the result of interaction within coastal areas, it may be that the limit on total yield (biomass) is established there and not by the "basic productivity of the ocean range" (e.g. Anon. 1980a, p. 9). In a portion of the system, i.e. the Fraser River, we may ponder the result, in terms of mean weight of even-year fish by statistical area, were the number of adults of the Fraser to return to the level of abundance believed to have existed prior to the fishery; extrapolation of the regression line of Figure 1 to greater abundance indicates that reduction in size would follow. Clearly the often used phrases, "historic catches", "historic levels", "depressed levels of abundance at this time" and "former state" (Larkin 1974, 1975, 1977; Foerster 1968, p. XV) as specific statements about the Fraser River, may be misleading, for no amount of juggling of catch statistics can alter the result that neither the level of abundance nor the average size at any time prior to the fishery is known.

4) In the development of Figure 1, I had utilized two independently derived groups of data:

   (1) estimates by the Salmon Commission of the number of pink and sockeye returning to the Fraser (e.g. Anon. 1978) and

   (2) mean whole weight of pink salmon caught by a non-selective fishery, i.e. by purse seine, in ten statistical areas (Ricker et al. 1978).

From the eight years of data in each of the ten areas a correlation coefficient was estimated (see tabulation in Figure 2) and their distribution contoured, but with some departure from rules of contouring. In addition, the gradient normal to the coast is an artifact and rests on my notion that the interaction that produces barren streams occurs seaward of the fjords and inlets, i.e. in the coastal portion of most statistical areas. Data do not exist toward the Fraser as few fish are caught by seine there in even years. But consider that data on even-year size in a non-selective fishery were available for statistical areas in southeast Alaska (such data likely exist but I have not been able to obtain them) so that for each area the regression of size on level of abundance of Fraser fish were possible. This would allow the extension northwestward of the contouring of Figure 2 and I speculate that the correlation would become less significant with distance northwestward from Dixon Entrance and Chatham Sound. I had supposed it would be necessary to examine statistics on Asian stocks to obtain data on size in the absence of trolling (Barber 1980, p. 8); however, the comments (Anon. 1979, p. 12) that "Prince William Sound has primarily a purse seine fishery for pink and chum salmon" and that the Bering and Copper River districts there "are exclusively gillnet fisheries for chinook, sockeye, and coho" suggested that the average weights of pink salmon determined for the sound might be considered the result of a non-selective fishery in the absence of trolling. As Ricker et al. (1978, p. 37) showed for Prince William Sound, a decline in size is not indicated, i.e. in an area where trolling

is not a significant fishery for pinks a recent decline in size has not occurred. Furthermore the regression of mean weight of even-year fish caught in Prince William Sound on abundance of Fraser pink and sockeye in odd years (Table 1) indicates a positive and not significant coefficient (+0.37). The result does not supplant the requirement for data from southeast Alaska but, while I did not anticipate interaction between Fraser adult and fry from the sound, the result does support my speculation about the interaction in southeast Alaska. I assume coherence in returns to the Fraser River and to the streams in southeast Alaska does not occur, i.e. there is not a systematic relationship in the variation of returns each year to the two areas. Godfrey (1958) concluded that while major stocks of pink salmon in British Columbia "exhibited quite similar annual variations in survival" the stock of the Fraser "behaved somewhat independently." There is however one year, 1965, in which the return of Fraser pink salmon, i.e. of the 1963 brood year, was low and in which returns were low to other streams along the coast:

> ...the 1965 Fraser River pink salmon run was only slightly better than the poor return in 1961 and totalled approximately 2,000,000 fish. This was the first time on record that such a small run occurred when environmental conditions for young fish in the Gulf of Georgia were favorable. However, it should be noted that the return of pink salmon along the entire Pacific Coast in 1965 was far below the expected level of abundance. What caused this general decline in abundance of pink salmon has not been assessed to date by any of the fisheries agencies involved (Anon. 1966, p. 21).

Table 1. Number of adult pink and sockeye to the Fraser River in odd years (1959-1973) as derived from annual reports of the Salmon Commission (Barber 1980, p. 11) and the mean whole weight of pinks caught the following even year in Prince William Sound (from Ricker et al. 1978).

Year of Return	Number ($X10^6$)	PWS (lb)
1959	10864	3.1
1961	6583	3.0
1963	9126	3.9
1965	5000	3.8
1967	19240	3.6
1969	8808	4.0
1971	17311	4.4
1973	13667	4.6

5) Cannibalism is believed central to extreme disparity, but whether size selection is of significance to the mechanism that produces extreme disparity is not known. Selection for large size in predation eventually could reduce the ability of adults to reproduce, just as could selection in a fishery (Ricker et al. 1978, p. 22). As small size does not appear to have been a factor in the failure of transplant experiments (Neave 1965) I assume selection for size does not bear on extreme disparity. That pink salmon in British Columbia are generally larger than those from Alaska and much larger than the pink in western Alaska (Ricker et al. 1978, their figure 3) supports this assumption.

There is a similarity between the experiments I propose and those carried out by Bilton (1978) and by others, e.g. Wallis (1968), but it is only in Bilton's work with coho that smaller size is specifically related to returns; he remarked, "for both male and female adults, there was a decrease in percentage return to the escapement with increasing smolt size." Jacks do not occur in pink populations, which to experiment would be a simplification, but it does not appear possible to arrange a unisexual experiment with fry, for the sex cannot be determined except by killing a sub-sample of the fish to be released (e.g. Bilton 1978, p. 3). Whether sex would be complicating in an experiment with pink salmon cannot now be addressed, for while there was evidence for size-selection in survival of coho - returning females were larger and decreased in number relative to the number released, whereas males increased (Bilton 1978, p. 8 and 13) - there is the possibility that the behaviour of fry may differ with sex. In another report on the experiment at Rosewall Creek, Bilton (1980) noted "an inverse relationship between smolt size and percent return of adults" for the release in April, i.e. at a time close to that of the normal outmigration.

6) The use of sea-going pens appears to meet many of the requirements of the experiments, including those of protection from predation, of feeding and of imprinting, i.e. imprinting fry with the character of the home region, while seaworthiness is assured as the main structure is the robust "flat boom" used to move logs in the forest industry, i.e. a flat framework of 60' boomsticks and swifters coupled with boomchains (Anon. 1945; frontispiece). Several additional swifters seem required in order to retain shape and to provide for attachment and hanging of the pens. Individual pens are suspended from the main structure with "chimneys" to the surface for feeding (Kennedy 1973; Brett 1974b, p. 75). Experience suggests it may be necessary to suspend the pens well below the surface to avoid motion sickness. Pens would be just under 20 feet on a side and 20 feet deep (Ryan 1975; Kennedy 1975) so that in each section there could be nine pens. While the structure may withstand reasonable surface wave activity it is meant to be guided, rather than towed, with passage through the water not exceeding 0.5 knot. Some difficulty may be foreseen in the transit of Masset Sound and care would be required in the shallow ground in the seaward approach where it may be prudent to reduce the draught of the pens.

There is an increasing literature concerning cage systems (e.g. Anon. 1976a; Novotony 1975; Huguenin and Ansuini 1978), but I did not find reference to a sea-going system, although it may be that adequate transport could be achieved by barge (e.g. McCabe et al. 1979).

7) It seemed useful to describe the setting for experiment by reference to a particular geographic location. As well I am advised that retention of young coho for significant periods at sites further removed from the open ocean causes many of the released fish not to move into the ocean, i.e. they remain close to the site (S. B. Mathews, personal communication; see also Mathews and Buckley 1976, p. 1681; Mathews and Olsen 1980, p. 1374).

8) It appears accepted that some ocean-coast streams without significant runs of odd or even-year fish were barren due to unknown factors; factors that would defeat an attempt at stocking, for as a run in neither year existed the stream was not suitable. Nevertheless, there have been attempts to stock such a stream, e.g. Robertson Creek (MacKinnon 1960; Lucas 1960; Boyd 1964; Neave 1965, p. 7; Ricker 1972; Aro 1979). Streams along the west and east coasts of the Queen Charlotte Islands have been described in terms of their apparent suitability and annual escapement (Marshall et al. 1978a; b). Streams on the west coast there are generally short, without storage (lakes) and show damage due to erosion (Marshall et al. 1978a). A few show evidence of significant even-year runs, e.g. Tartu Inlet Creek (p. 232), and in several streams a run occurs in both years, e.g. Riley Creek (p. 196); the summary record for the west coast (p. ix) indicates an escapement in 1952 of over half a million pinks, while in one odd-year (1965) an escapement of 35,000 occurred to Riley Creek. As Riley Creek has had returns in some odd-years I considered that an experiment with this year class might be carried out there. But as it might not self destruct (Hackney 1979, p. 117) it appeared prudent to avoid the site initially, i.e. adults could interact with sea-going fry on the even-year class, particularly those from the north coast of Graham Island, so that a positive result in this second experiment could lead to a disbenefit in number of returns in the even-year to another area.

9) This result could have been usefully used in the speculation about the origin of pink salmon (Barber 1978).

10) Presumably this would be achieved by use of half-length coded wire tags and by arranging to retrieve all returns at the creek and from the fishery (e.g. Jewell and Hager 1972; Anon. 1976b; Undated a, p. 40), but there are drawbacks (Anon. Undated b, p. 58).

11) This is the estimate of the Salmon Commission of the number of pink and sockeye returning to the Fraser River, which I presume would still be possible even though the more intense fishery occurred.

12) I recall gillnetters on Inverness Passage in 1932 talking about the occurrence of off and on years in the Masset Inlet fishery. They may have had a unusual interest that season for pink runs to both the Skeena and the northern Queen Charlotte Islands were down that year (Neave 1966; Howe 1933). The industry in the Queen Charlotte area was relatively more dependent on pink salmon and in most odd years many canneries did not operate; the use of a floating cannery (Fig. 5) may have been a response to the existence of extreme disparity in that area.

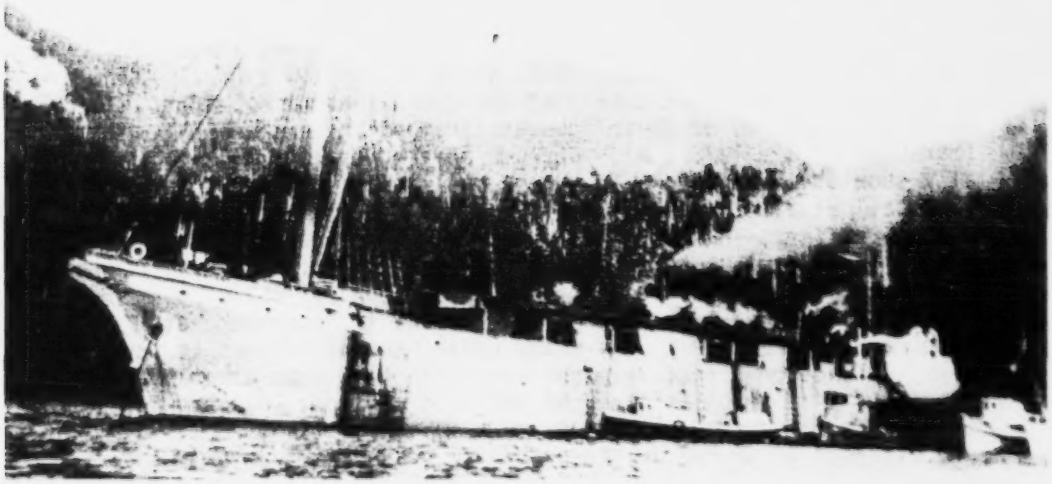

Fig. 5. The *Laurel Whelan* in 1925 at Barnard Harbour in Wright Sound employed as a floating salmon cannery which included a steam plant with two lines; in the 1926 season it was located in Ferguson Bay in Masset Inlet (personal communication Axel R. Larson, Port Alberni). The vessel was converted from a five-masted barque by the Francis Millerd Packing Company (Blyth Undated; see also Lyons 1969, p. 358 and 402; Anon. 1927, p. 19 and 20).

13) The translation (Notkin 1934) of the article by Baranov does not include the phrases "fishing-up period" or "the removal of accumulated stocks."

Note added in proof: data on mean round weight of even-year fish caught by purse seine in thirteen statistical areas in southeast Alaska have been provided by the Department of Fish & Game of the State of Alaska.